VIBRATIONAL SPECTROSCOPY OF SYMPATHETICALLY COOLED CaH^+ MOLECULAR IONS

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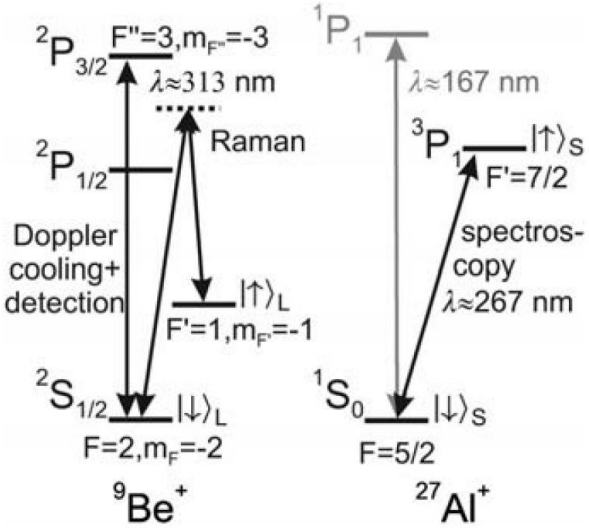
Motivation and background

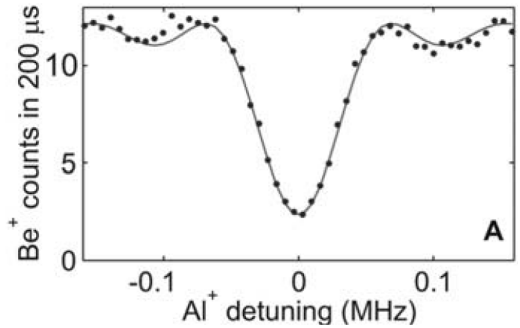
- Time variation of fundamental constants such as α and μ
- Detected astronomical variations in α of one part in 10^5
- Comparison between red shifted quasar spectra and laboratory measurements
- Precision spectroscopy can be performed on cold molecular ions

NASA

Why cold molecular ions

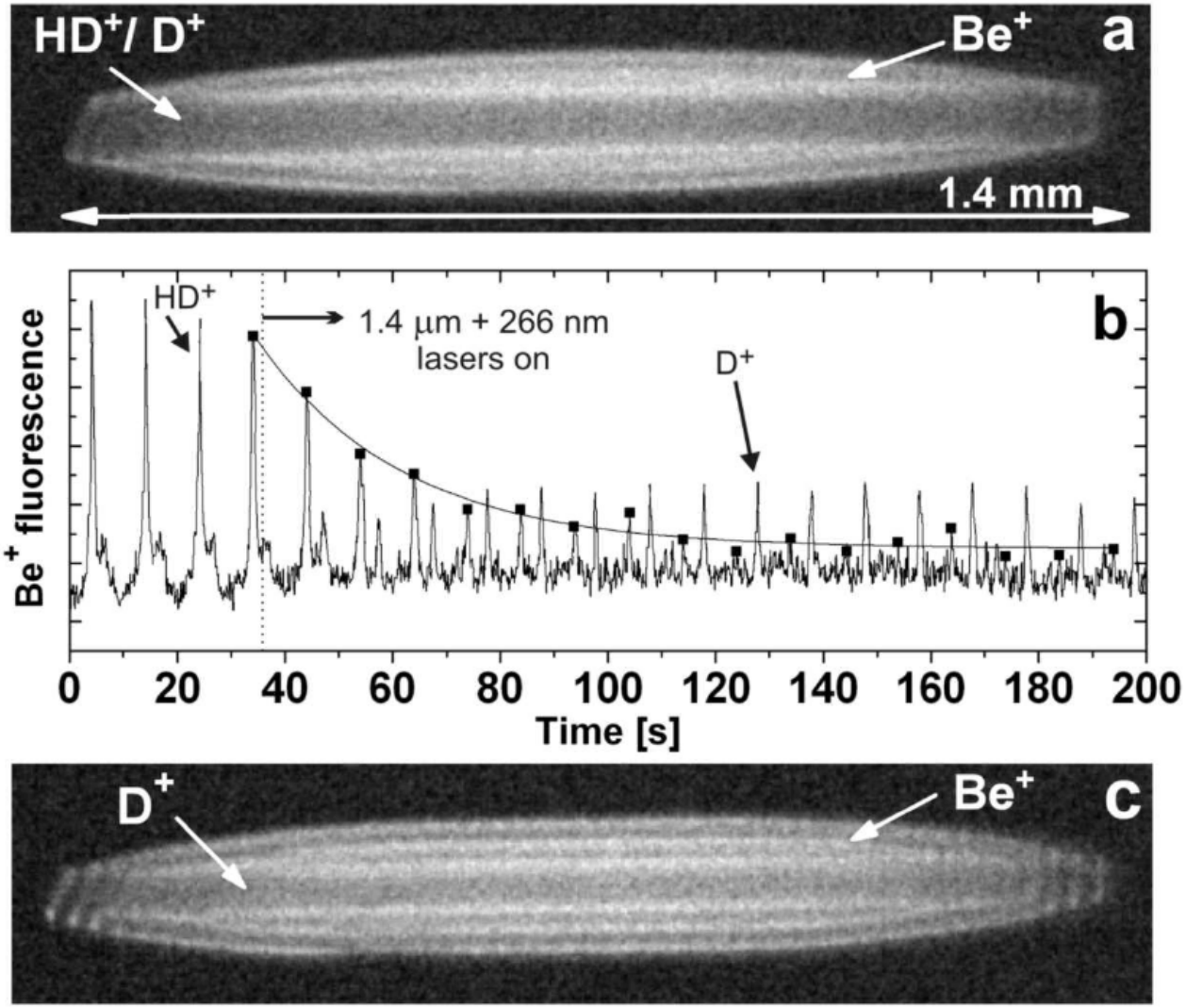
- Vibrational and rotational transitions depend on μ
- Atomic transitions have smaller shifts $\approx 10^{-5}$ while molecules ≈ 0.5
- Can be trapped with rf and DC fields along with laser cooled atomic ions i.e. sympathetically cooled
- Motional coupling of ions allows for precision measurements
- Lack of experimental data





Schmidt, P.O.,*et al.*,*Science* **309**,749(2005)

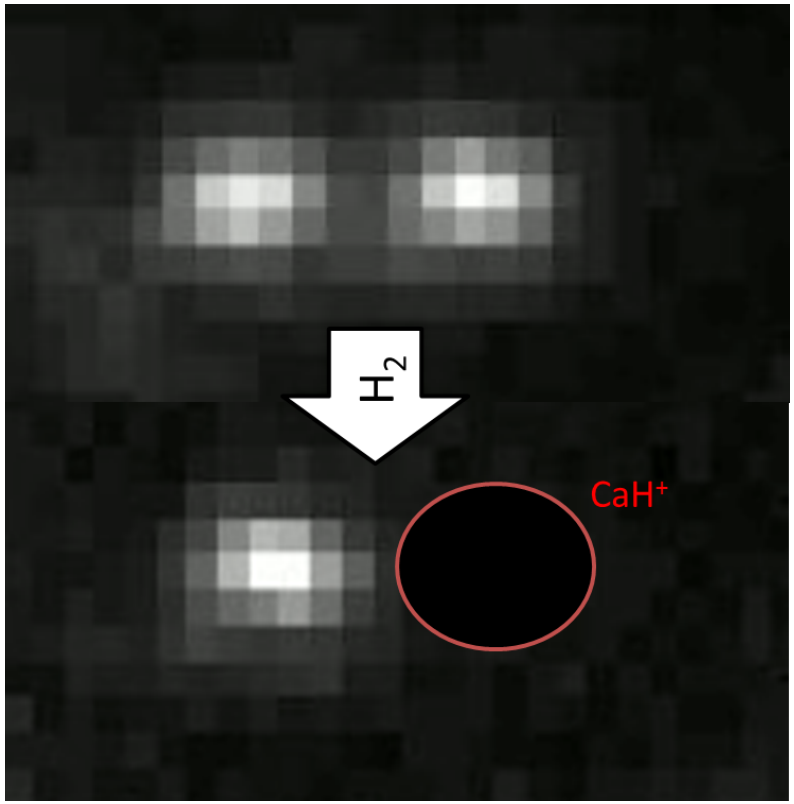
Spectroscopy with sympathetically cooled ions



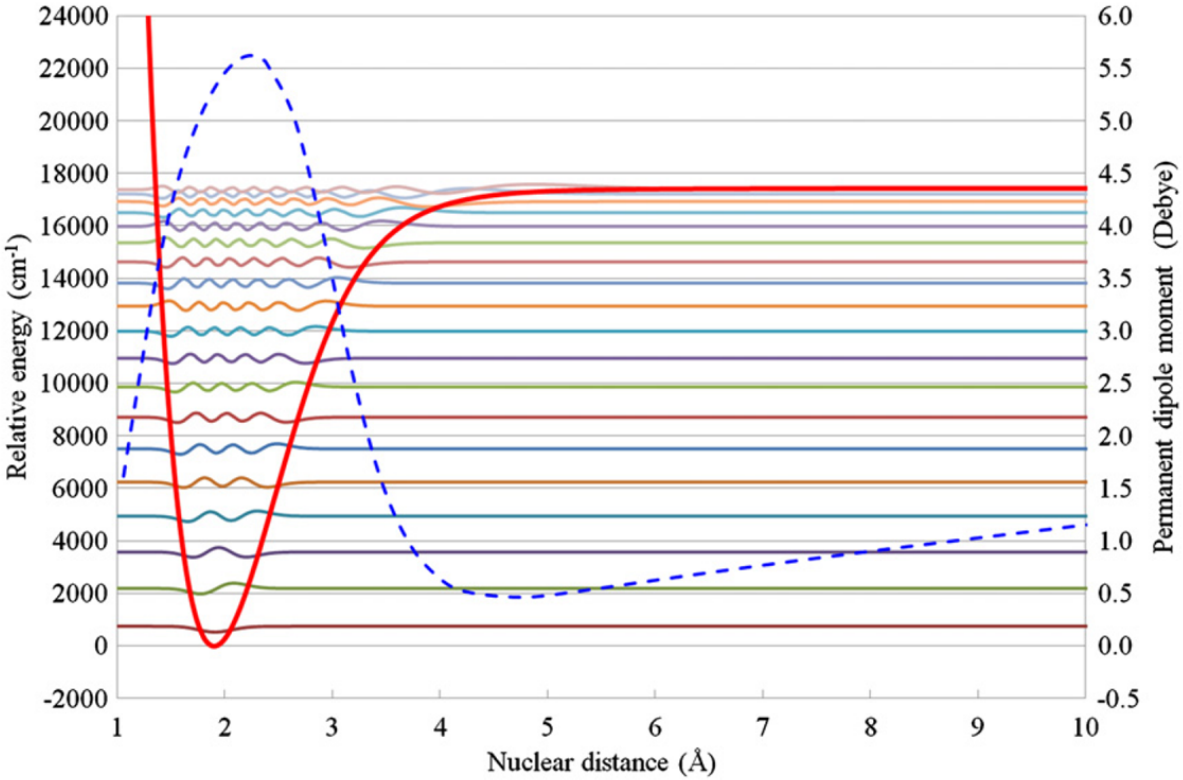
Roth, B.,*et al.*,*Phys.Rev.A* **74**,040501(2006)

Why CaH^+?

- Abundance of H in space means formation of CaH^+ very likely
- Easily prepared by $^{40}Ca^+ + H_2 \rightarrow {}^{40}CaH^+ + H$
- Can be prepared in well defined vibrational and rotational states
- predicted upper bound limit $\approx 10^{-15}$



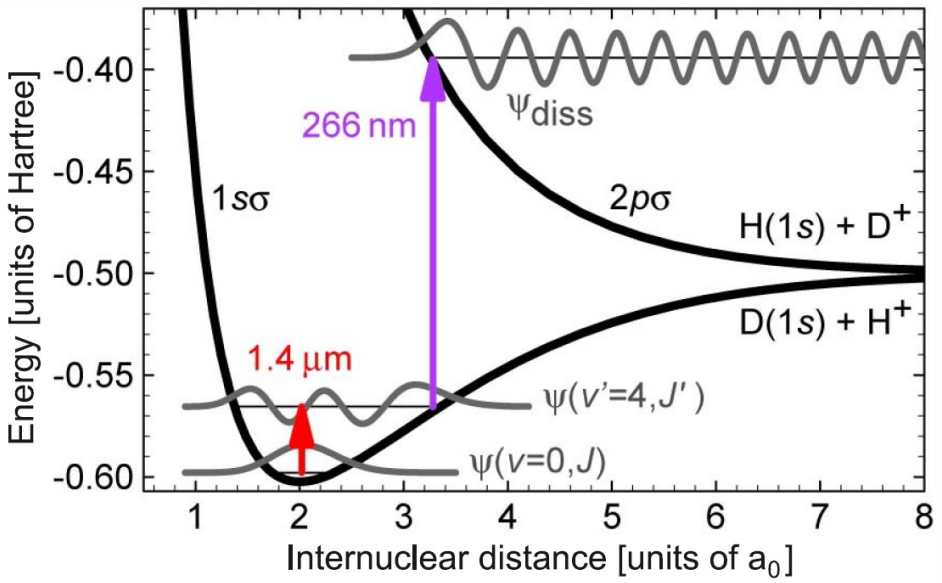
CaH^+ vibrational overtones



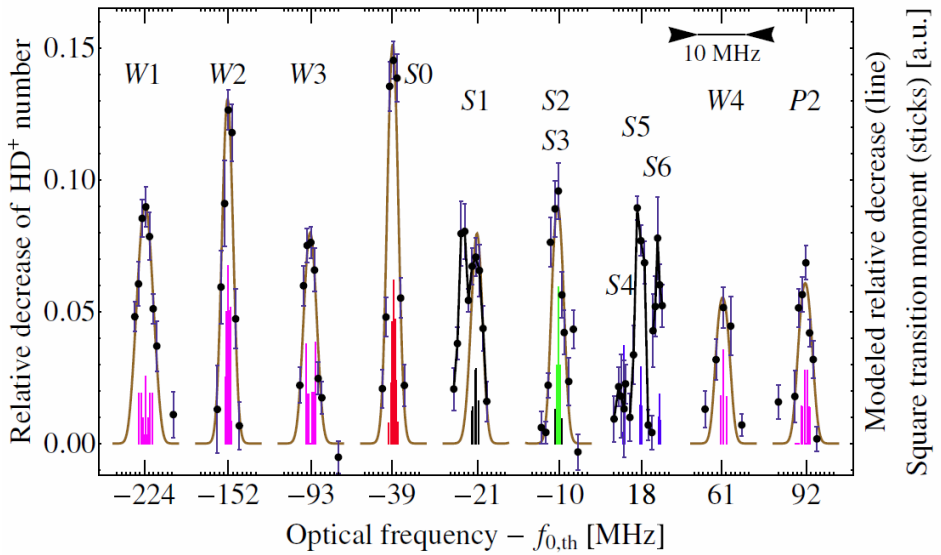
Overtone	λ[nm]
$0 \leftarrow 9$	883.9
$0 \leftarrow 10$	813.8
$0 \leftarrow 11$	758.3

Abe, M.,*et al.*,*J. Phys. B: At. Mol. Opt. Phys.* **43**,245102(2010)

Resonance Enhanced Multiphoton Dissociation (REMPD)

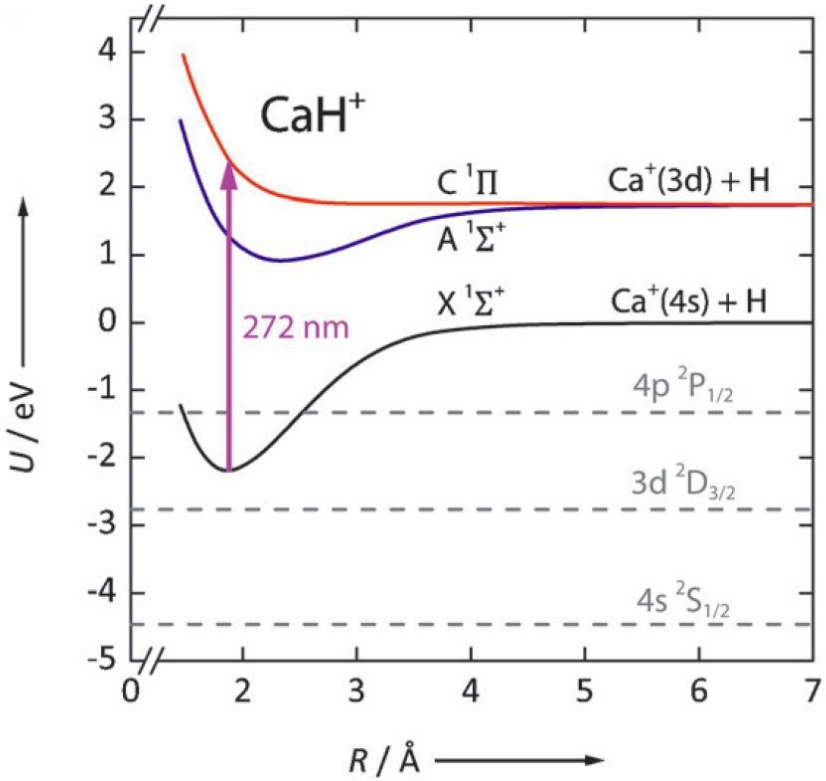


Roth, B.,*et.al.*,*Phys.Rev.A* **74**,040501(2006)

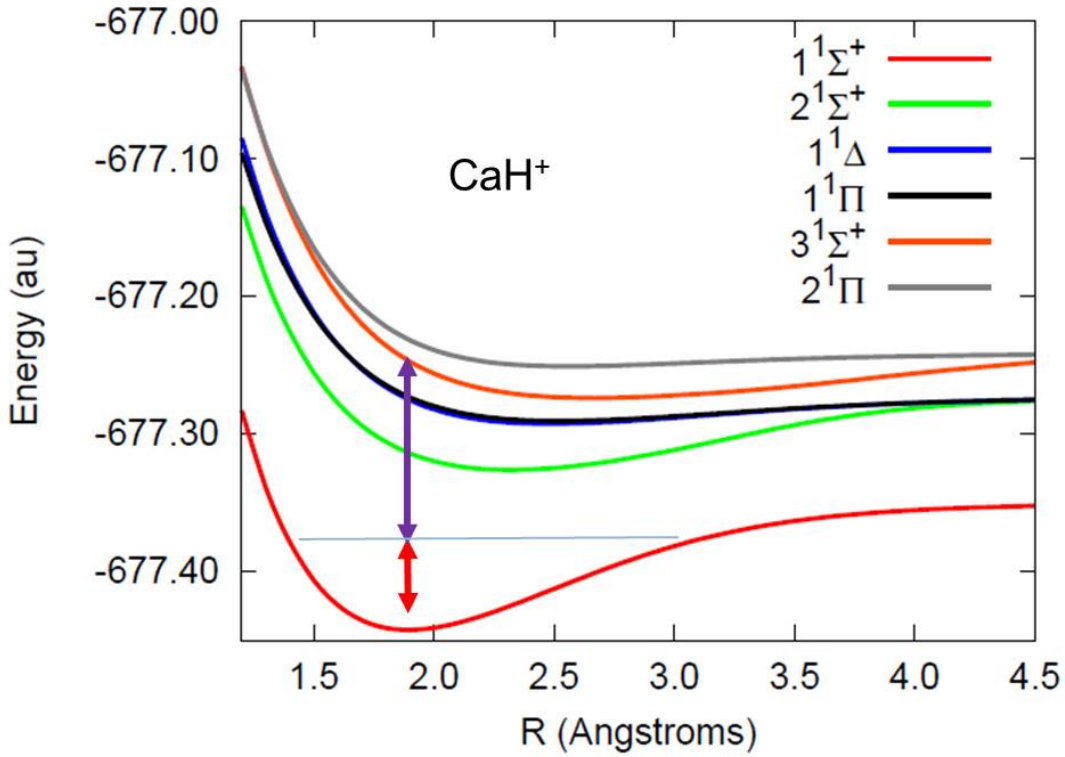


Bressel, U.,*et.al.*,*Phys. Rev. Lett.* **108**,183003(2012)

CaH^+ REMPD



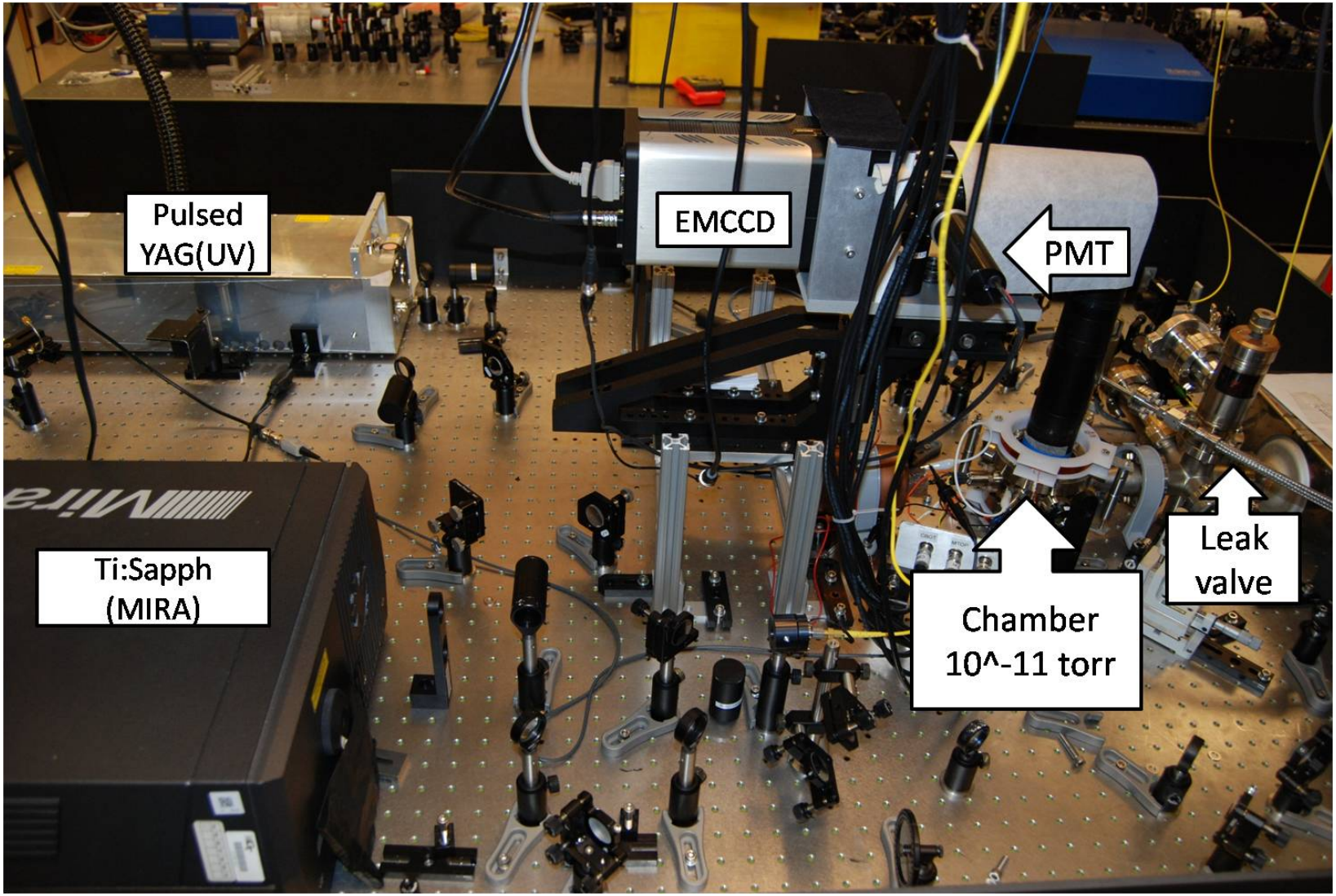
Hansen, A.K.,*et.al.*, *Ang. Chem. Int. Ed.* **51**,7960(2012)



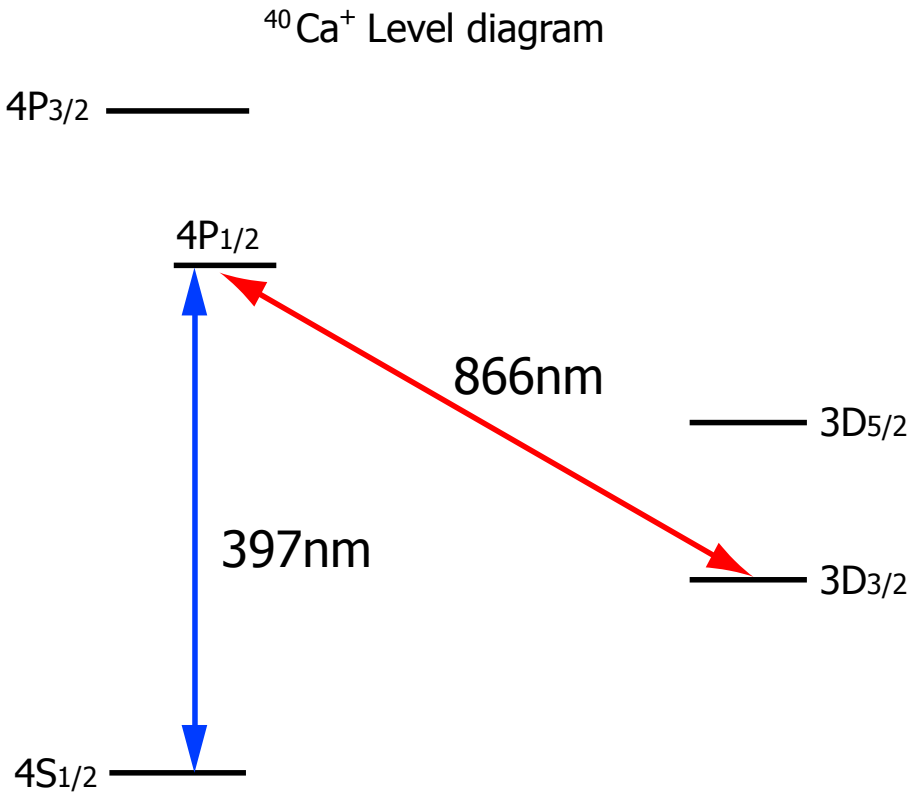
In collaboration with Ed Hohenstein and David Sherrill

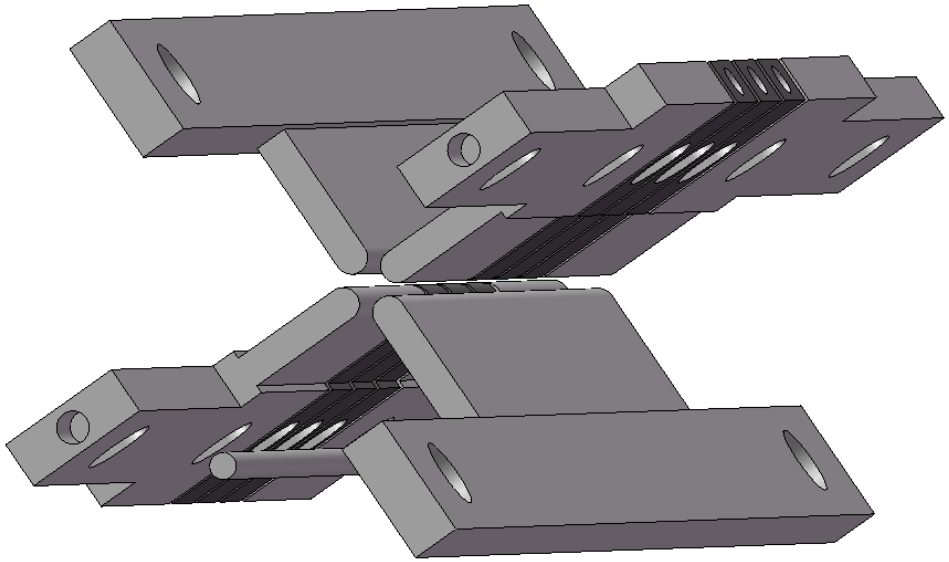
- CaH^+ use IR(750-900nm) and UV(355nm) for REMPD

Experimental setup

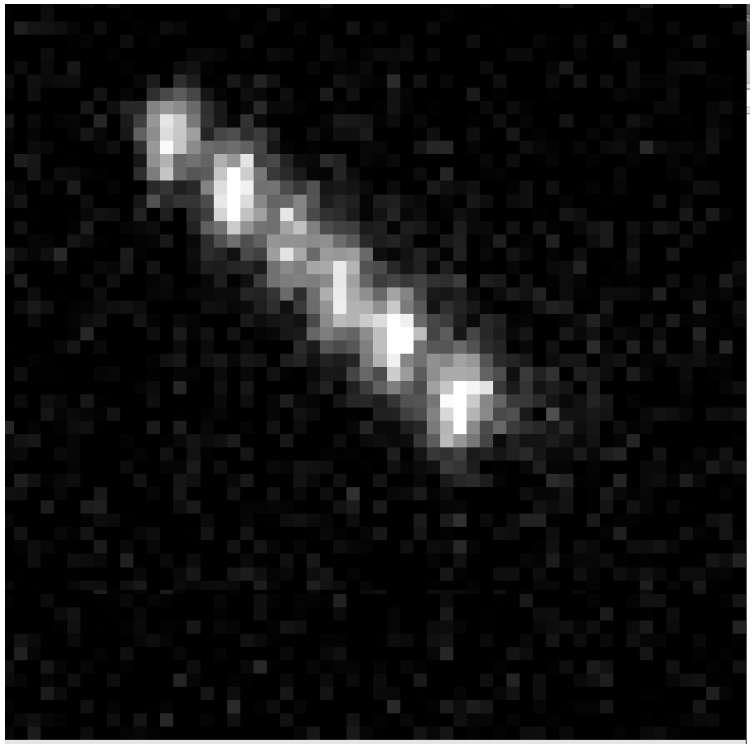


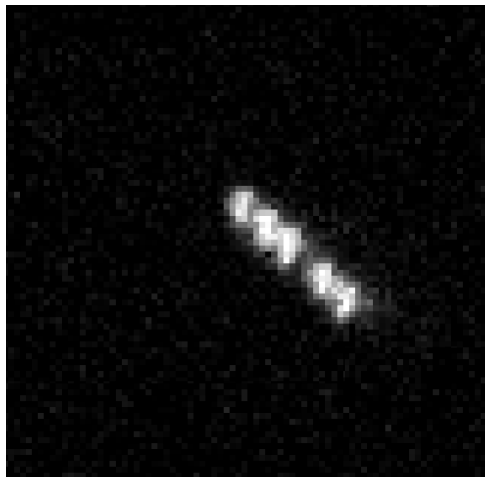
Experimental setup *cont.*

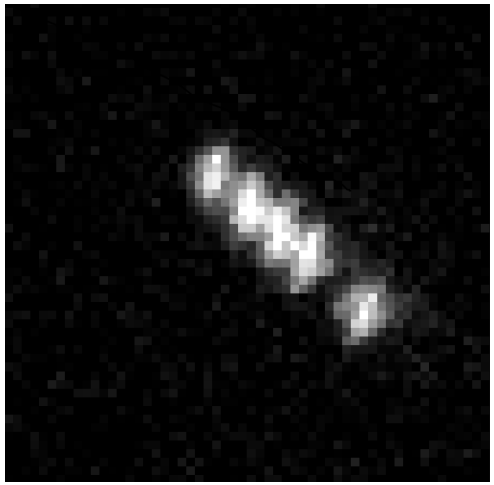




Single molecule reactions

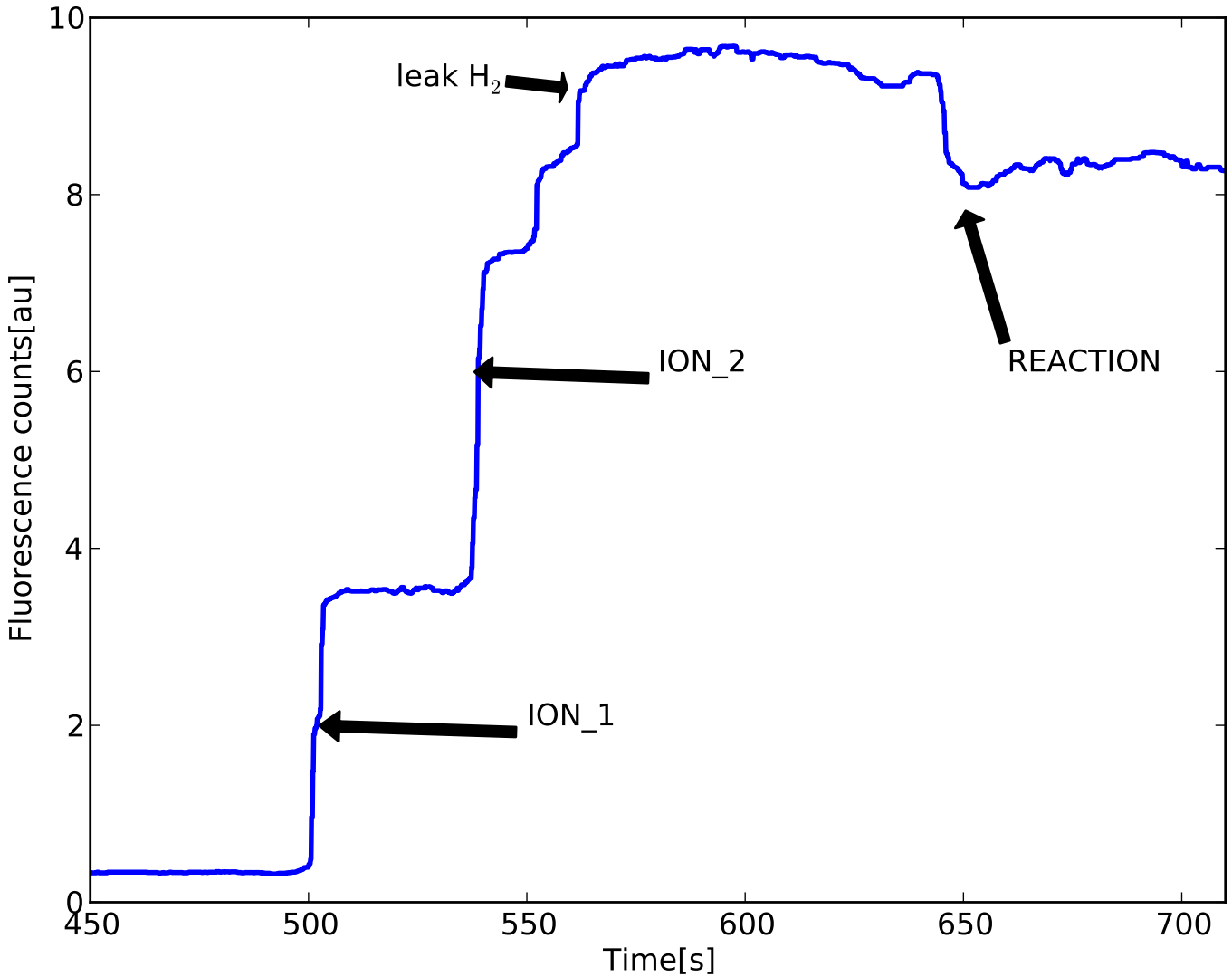




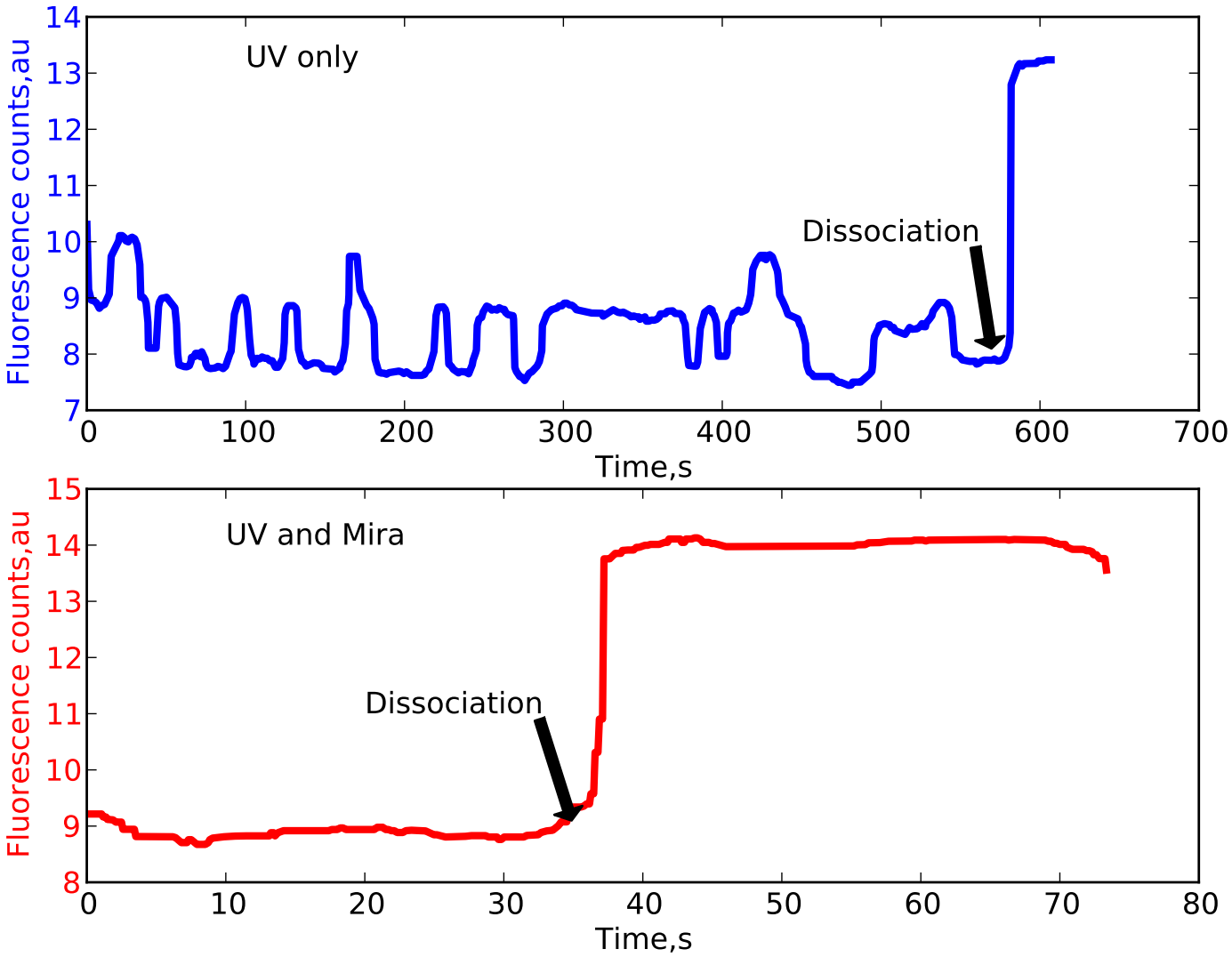


0 20 μm

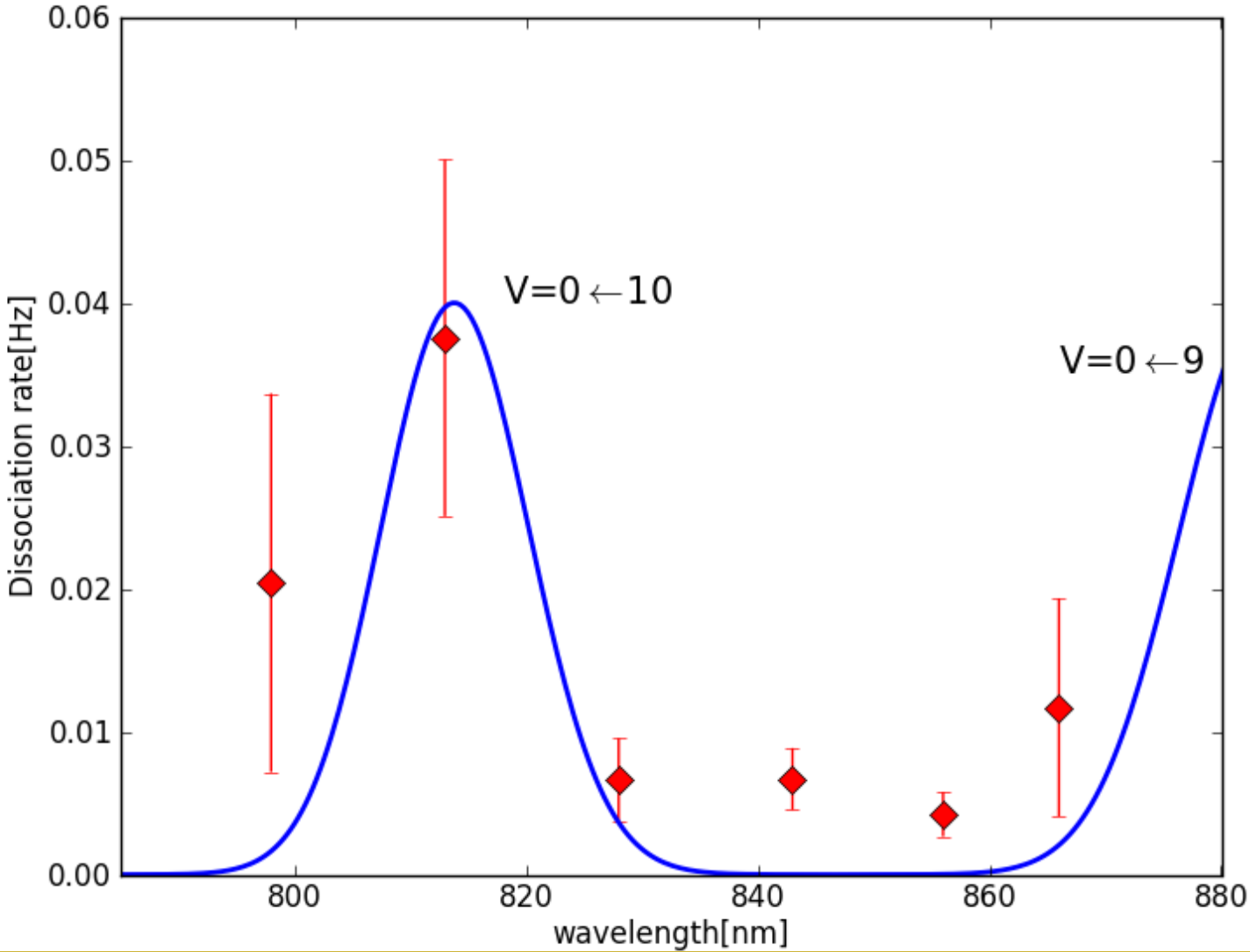
Single molecule reactions



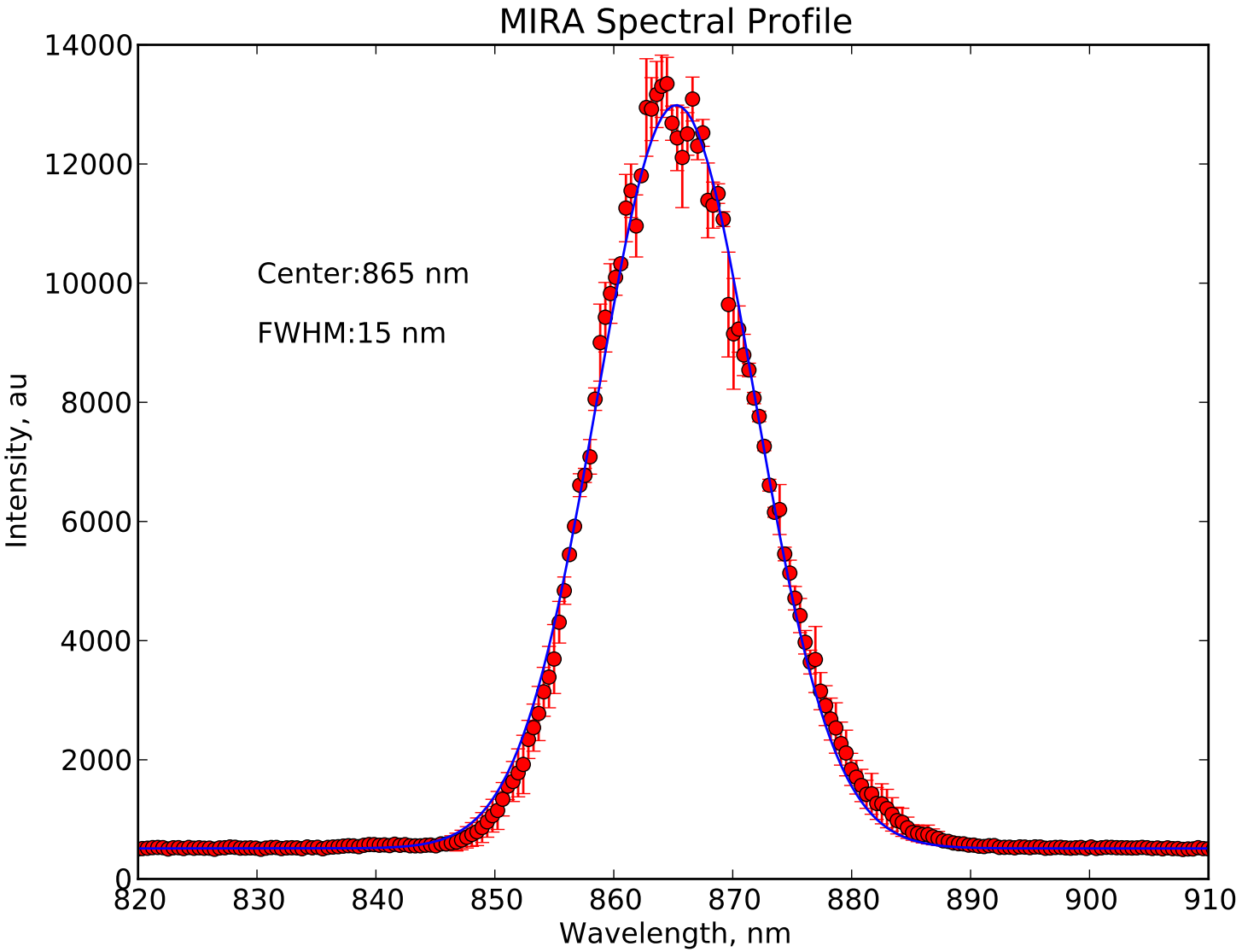
REMPD rates


UV only
Dissociation
Fluorescence counts,au
Time,s
UV and Mira
Dissociation
Fluorescence counts,au
Time,s

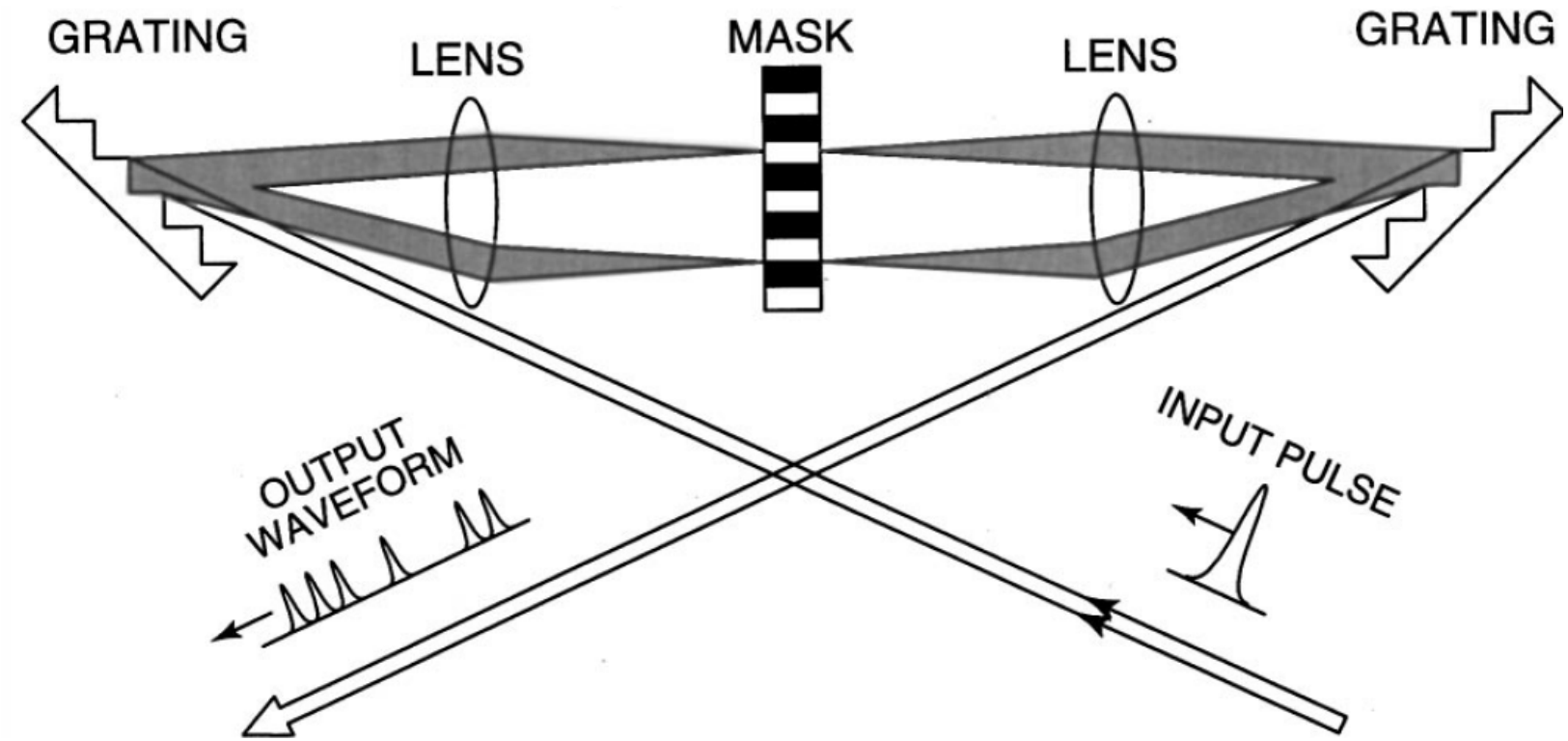
The $V_0 \leftarrow V_{10}$ (813.8nm) vibrational line



Mira profile



Towards precision measurements



Weiner, A.M., *Rev. Sci. Instrum.* **71**,1929 (2000)

Conclusion and future work

- Atomic ion laser cooling techniques can be used to assist precision molecular spectroscopy
- Using REMPD, we have been able to show preliminary measurements of CaH^+ overtone
- We are setting up experiments to measure vibrational and rotational spectra of CaH^+
- We are working towards directly laser cooling a molecular ion, BH^+

Acknowledgments

ww2.chemistry.gatech.edu/brownlab